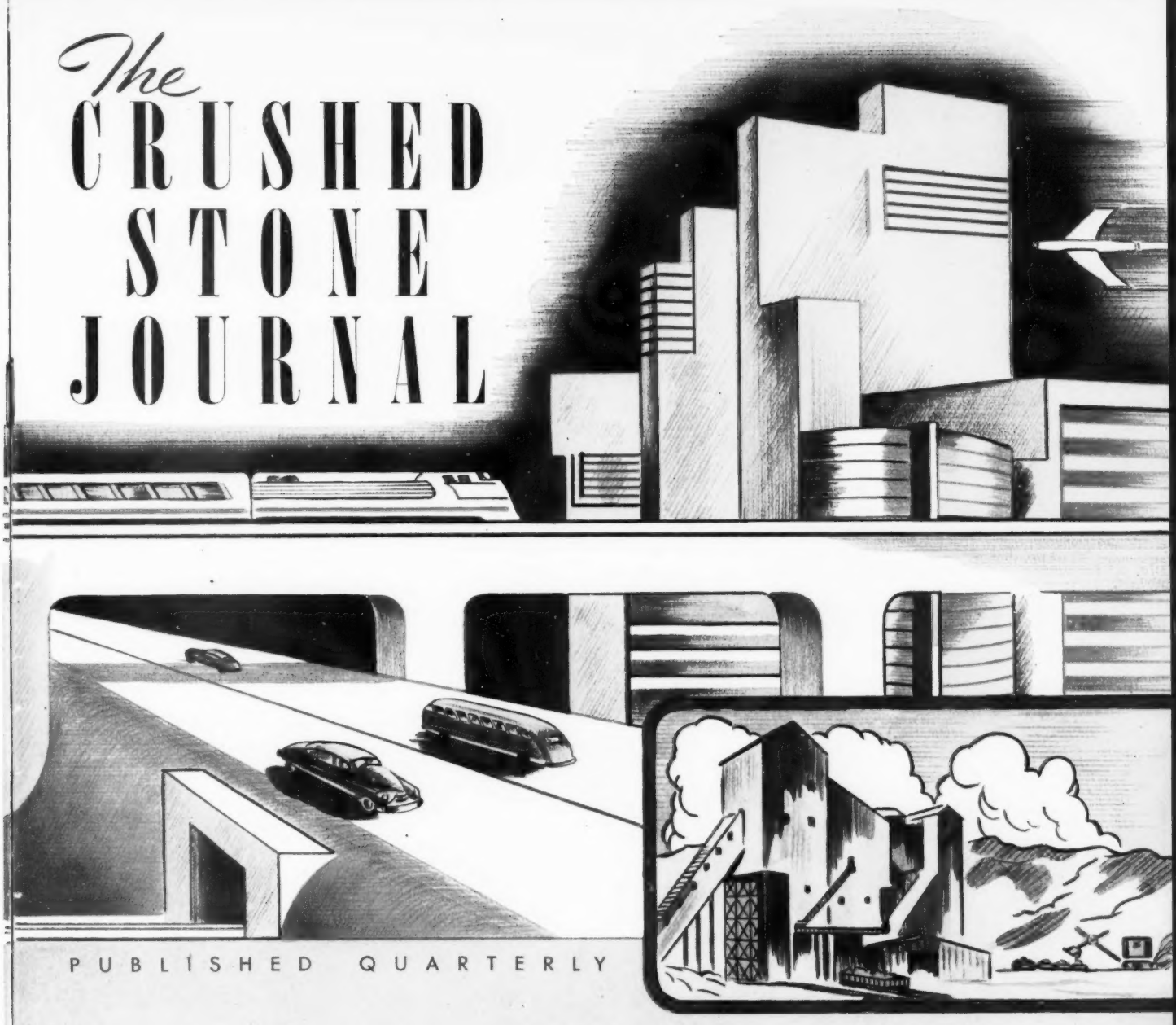
The CRUSHED STONE JOURNAL



PUBLISHED QUARTERLY

In This Issue

December 1950

- Cincinnati Convention Offers Impressive Program
- Aggregates and Pavement Life
- Crushed Stone Output in 1949
- Newly Authorized Federal-Aid Funds Apportioned
- Highway Research Board Report of Progress, Road Test One-Md.

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The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

NATIONAL CRUSHED STONE ASSOCIATION

1415 Elliot Place, N. W.
Washington 7, D. C.

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LAST CALL!!!

34th ANNUAL CONVENTION
National Crushed Stone Association

6th ANNUAL CONVENTION
Agricultural Limestone Institute

Netherland Plaza • Cincinnati, Ohio

WEEK OF FEBRUARY 5, 1951

THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XXV No. 4 PUBLISHED QUARTERLY DECEMBER 1950

Cincinnati Convention Offers Impressive Program

PROGRAM arrangements for the 34th Annual Convention of NCSA are now substantially complete and assure those privileged to attend these two outstanding events of the year for crushed stone producers a highly profitable and thoroughly enjoyable experience.

Mobilization of our armed forces and economic strength to meet the march of world events which threaten the safety and security of our nation will intensify many of the current problems of our industry and bring into being many more which necessarily go hand and hand with increased governmental regulations.

It is timely indeed that this annual convention is to take place when the problems of mobilization are coming into sharp focus.

Prominent authorities in and out of government will talk on subjects of vital and basic importance to the effective conduct of your businesses under a controlled economy. To hear these speakers will be both interesting and informative and better prepare you to cope with the difficulties which lie ahead.

It is highly appropriate that there has been scheduled an increased amount of time for the consideration of practical operating problems, for not since World War II has it been so necessary to utilize and conserve production facilities to the utmost.

The sessions on Monday afternoon and Wednesday morning will deal with just such matters and should alone make the trip to Cincinnati a profitable and very much worthwhile investment.

A number of features on the Cincinnati program warrant your especial attention. At the Greeting Luncheon on Monday, Rear Admiral Ellis M. Zacharias, U.S.N. (Ret.), former Deputy Director of Naval Inteiligence and author of the best-sellers, "Secret Missions" and "Behind Closed Doors," will speak on "Today's World—Tomorrow's Peace." Since his retirement from the Navy in 1946, Admiral Zacharias has maintained the clear-thinking, accurate sense of responsibility which made his work so valuable to the Navy as an able prophet of future military events. His message should be deeply significant in view of the present trend in world affairs.

"Macadam Construction by New Machine Methods" will open the Tuesday morning session in the form of a moving picture with running commentary by Fred E. Swineford, Engineer-Director of Macadam Pavements, Inc. Demonstrating as it does the means for making the macadam base much more effective for carrying heavy wheel loads, this presentation should be of unusual interest.

"The Importance of Highways to National Defense" will next be discussed by the new Executive Vice President of the American Road Builders' Association, Lt. Gen. Eugene Reybold. No comment from us is needed to emphasize the timeliness of his subject, and by both experience and position he is exceptionally well qualified to present it.

Also on Tuesday morning, O. J. Porter, Consulting Engineer of Newark, N. J., will talk on "The Design of Pavements for the New Jersey Turnpike." This project is of special interest in that the flexible type has been placed in competition with concrete and the respective designs are made for carrying the heaviest wheel loads in the country. The value of such a paper to the crushed stone industry is apparent.

The rapidly accelerating mobilization of manpower for the Armed Forces makes the topic, "Man-

power Problems as Related to Selective Service," scheduled for Wednesday afternoon, of vital importance to every crushed stone producer. The speaker on this subject is Joel D. Griffing, Colonel, Infantry, Chief, Manpower Division, National Headquarters, Selective Service System. With the liquidation of the Selective Service System of 1940-1947, Col. Griffing came to Washington with a small planning group, wisely retained by Gen. Hershey against the hazards we now face, and with the enactment of Selective Service in 1948, Col. Griffing became Chief of the Manpower Division. His information will be authoritative and should prove of real value to those facing the loss of men to the draft.

Government's recent request for voluntary price controls certainly foreshadows more rigid regulation of both wages and prices. Developments in this field are taking place almost from day to day and we can be sure of the latest authoritative information when John C. Gall speaks on "Wage and Price Controls," on Tuesday afternoon.

For the Luncheon on Wednesday (joint with the Agricultural Limestone Institute) it is especially pleasing to announce a return engagement of Harold G. Hoffman, former Governor of New Jersey, who made such a hit at our New York Convention in 1948. He will have as the intriguing title of his address, "Gripes and Grins." As the concluding part of his talk he will present the Safety Awards for the 1949 NCSA Safety Contest.

"Shop Talk on Employee Relationships" will be presented on Wednesday afternoon by Hiram S. Hall, Vice President for Personnel of Bigelow-Sanford Carpet Company. Mr. Hall has a most extensive experience in the field of labor relations. He is

(*Continued on Page 16*)

LT. GEN. EUGENE REYBOLD
"The Importance of Highways to National Defense"

HAROLD G. HOFFMAN
"Gripes and Grins"

O. J. PORTER
"The Design of Pavements for the New Jersey Turnpike"

REAR ADMIRAL ELLIS M. ZACHARIAS U.S.N. (Ret.)
"Today's World—Tomorrow's Peace"

HIRAM S. HALL
"Shop Talk on Employee Relationships"

JAMES E. GHEEN
"Little Do We Know"

COLONEL JOEL D. GRIFFING
"Manpower Problems as Related to Selective Service"

JOHN C. GALL
"Wage and Price Controls"

Aggregates and Pavement Life*

By A. T. GOLDBECK

Engineering Director
National Crushed Stone Association
Washington, D. C.

THAT aggregates do affect the life of any type of pavement is a conclusion which is founded on observation and experience, but it must not be assumed that aggregates alone control pavement durability, for such an assumption would be erroneous. There are many other life-controlling factors whose influence may far out-weigh the effect of the aggregate.

Let us consider only the portland cement concrete pavement which falls in the category of the so-called rigid type, and let us see how the aggregate may at times govern the duration of its useful life. To fully understand the behavior of a concrete pavement slab and the part played by the aggregate, it is important first to remember that in the normal pavement concrete, the total volume occupied by the combined fine and coarse aggregates is approximately 70 to 75 per cent, and the volume of the coarse aggregate is over 45 per cent of the volume of the concrete. Of the four principal concrete constituents, the coarse aggregate occupies the largest volume, and so there is good reason why it does play a vital role in controlling the quality of the concrete, and hence, its life. But the aggregaate is glued together by the portland cement paste, and if there is anything wrong with this glue, it, too, has a vital influence. Although we have set out to examine the aggregate effects alone, we have not forgotten that the aggregates are not the sole influence on pavement life.

Effect of Aggregate on Bending Resistance

First, what kind of a structure is a concrete pavement slab? What are its charteristics? And to what kind of attacks is it subjected when performing its traffic-carrying function? A concrete slab differs from all other types of pavements in that it possesses rigidity; it can deflect very little without cracking. Unlike the flexible type, such as bituminous concrete on a macadam base, it possesses what the engineer calls "resisting moment." It resists bending due to external forces, such as wheel loads, which produce internal forces, called stresses, in the concrete—sometimes compressive, sometimes tensile stresses. Highway concrete is strong in compression, with an ultimate compressive strength of around 5000 psi., but it is relatively weak in tension, with tensile values of only some 400 psi. when the tensile stress is produced directly, and around 700 to 800 psi. when produced by bending and calculated as "modulus of rupture." One seldom worries about lack of compressive strength in a concrete pavement, but high resistance to tension is important, for this affects the frequency of cracking.

It is here that aggregates have an effect on durability or pavement life, because it is a fact that the aggregates have an important influence on the modulus of rupture or beam strength of concrete. Tests have been made by a number of investigators, all showing that there is some relationship between the percentages of loss in the Los Angeles abrasion test on coarse aggregates and the modulus of rupture of concretes made with different coarse aggregates. Thus, tests reported by Woolf[1] show a range of modulus of rupture from about 880 psi. with stone having a Los Angeles abrasion loss of 20 per cent, down to about 640 psi. with stone having a Los Angeles abrasion loss of 60 per cent. Similar, although not identical data, have been obtained in North Carolina, Texas, and elsewhere, including the laboratory of the National Crushed Stone Association.

Effect of Thermal Coefficient of Expansion

It is not generally known that concrete pavements are quite universally built with practically no factor of safety against cracking, and especially is this so in pavements having a high intensity of traffic and, consequently, many repetitions of stress. Concrete suffers fatigue under loads repeated millions of times, with the result that the tensile stress at failure may be close to one-half of the modulus of rupture determined by means of a beam test, in which the load is applied once instead of millions of times. Thus, if the flexure test shows the concrete to have a modulus of rupture of 700 psi., then, under oft-repeated loads

* Presented before the Annual Meeting of the Indiana Mineral Aggregates Association, Indianapolis, Ind., February 23, 1950

1 D. O. Woolf—"The Relation between Los Angeles Abrasion Results and the Coarse Aggregates," *Proceedings*, 17th Annual Meeting, Highway Research Board; also, *Crushed Stone Journal*, July-August 1938

this same concrete may fail under a stress of only 350 psi. Then, too, it is to be remembered that not only loads, but also natural phenomena such as alternations of temperature and of moisture, are very active in producing high internal stress, no matter what kind of aggregate is used. Thus, the slab warps and humps up in the middle during the day and becomes dished at night. It actually lifts itself clear of the subgrade in spots and its dead weight, which tends to bear it down, then produces bending stress, sometimes equal to that produced by wheel loads; and it is here that certain physical characteristics of the aggregate become important.

One of these important characteristics is the change in dimensions which takes place in the aggregate when its temperature changes. The physicist designates this property by a numerical value which he calls the thermal coefficient of expansion, and by this he simply means the change in length per inch of length per degree of temperature. When we say a certain rock has a thermal coefficient of expansion of 0.000005, we mean that a piece of this rock one inch long will expand 0.000005 in. per degree Fahrenheit. The value 0.000005 is 5/1,000,000 or $5/10^6$. This equals 0.006 in. per 100 ft., and is 0.6 in. per 100 ft. for 100 F. change in temperature. The thermal stress due to warping is affected by the thermal coefficient of expansion of the coarse aggregate because concrete expands and contracts to about the same amount as the coarse aggregate. A large amount of expansion generally is accompanied by a large difference in expansion between the top and bottom of the slab, and hence more warping than when the thermal coefficient is small. A large amount of warping causes a greater length of slab to rise out of contact with the subgrade, and hence greater bending stress is created. More cracking, especially transverse cracking, is to be expected with aggregates having a high thermal coefficient of expansion than with those having a low thermal coefficient. Thermal coefficient obviously has a bearing on frequency of cracking, maintenance expense, and pavement life.

Much could be said about internal stress and its relation to cracking of concrete. Small differences in tensile stress resulting from bending have more effect on cracking than generally supposed, and the reason is that concrete suffers fatigue under repeated loads. When concrete is stressed in tension up to about 55 per cent of its modulus of rupture, there is evidence that it can be stressed millions of times, but if the stress exceeds this amount by very much, the number of times this increased stress can be applied without failure is very appreciably reduced. It is easy to see why one concrete resists cracking more than another from a consideration of its fatigue resistance alone. Suppose wheel loads stress a pavement up to 400 psi. The concrete with one aggregate has a modulus of rupture of 800 psi. and with another aggregate only 700. A stress of 400 is 50 per cent of 800 and is 57 per cent of 700. The first pavement will resist such stress indefinitely while the second pavement will fail by cracking in a few thousand load repetitions. Such differences in modulus of rupture are frequently due to the effects of the coarse aggregate. Incidentally, it is easy to see how overloading may cause excessive damage because of this same fatigue phenomenon, even though the overloading may seem relatively small.

Abnormally Low Thermal Coefficient

Sometimes aggregates are used which have an abnormally small thermal coefficient of expansion, and the evidence seems clear that such aggregates produce rapid disintegration of concrete which is exposed to severe changes in temperature. Pearson[2] describes the rapid failure of cast stone steps exposed to severe changes in temperature. The units, cast in 8-ft. lengths were dressed on two faces to expose the aggregate—a crystalline dolomitic marble from New York State. The concrete was well compacted by vibration and had a low water content, only 5½ gal. per sack. It should have been durable, but it failed during a single winter's exposure. Many tests of different kinds were made, and ultimately the cause of the failure was laid to the low thermal coefficient of expansion of the aggregate. This was close to 0.000002 per degree Fahrenheit. The thermal coefficient of cement is roughtly 0.000006 to 0.000009, 3 to 4 times as much as that of the aggregate. Consequently, during severe changes in temperature there was a tendency for the paste to expand and contract much more than the aggregate, thereby tending to cause a release of bond and cracking. Laboratory freezing tests on specimens made of this same New York marble and also with marbles from other sources and having a low thermal coefficient showed similarly poor durability. All marbles evidently do not give poor durability in exposed concrete. For illustration, the sign posts marking the

[2] J. C. Pearson—"A Concrete Failure Attributed to Aggregate of Low Thermal Coefficient," *Proceedings*, American Concrete Institute, Vol. 38, P. 29, 1942

sections in the Chevy Chase, Maryland, experimental road were in perfect condition after about 30 years of exposure. They were made with marble screenings including the dust, white portland cement, and 10 per cent by weight of cement of white mineral oil used to inhibit absorption.

Dust coating on stone and clay coatings on gravel may seriously reduce the strength of concrete and lead to lack of durability due to the unavoidable use of too much mixing water because of the finely-divided dust or clay. In one case, limestone coarse aggregate which was used, despite the presence of over 7 per cent of minus 200 mesh dust, required an abnormally high water ratio and was a contributing factor in the production of miserable concrete by an uninformed ready-mixed concrete plant. Tests on this concrete showed low results at 28 days. A small amount of dust does no harm, only about 1½ per cent reduction for each per cent of dust, but it is safest to keep the dust content as low as practicable.

Chert

Chert is sometimes, but not always, a bad actor. Chert is defined in different ways, but in general it is any light-colored cryptocrystalline rock composed of silica with certain impurities—impure, flint, chalcedony.

Sosman[3] seems to distinguish between flint and chert, but it would be difficult to readily distinguish these two by their definitions. Cantrill and Campbell[4] state the following: "Geological definitions of chert vary; however, the most widely used defines it as an impure flint and jaspar with crystals of pyrite and other foreign material."

Chert varies in its characteristics. Holland[5] presents the following values of apparent specific gravity and absorption:

Description	Apparent Specific Gravity	Absorption, per cent
Gilbertsville coarse, chalky chert	1.81	16.7
Gilbertsville fossil chert	1.95	2.5
Gilbertsville fine, chalky chert	2.11	6.3
Chickamauga fractured chert	2.49	2.4
Chickamauga massive chert (hard)	2.65	0.5

Note the large range in gravities and absorptions.

Wuerpel and Rexford[6] show increasing loss in the magnesium sulfate test in samples whose bulk specific gravity varied from plus 2.50 to minus 2.30. Among others they came to the following conclusions: "The accelerated physical tests such as freezing and thawing, magnesium sulfate, and absorption are useful but not satisfactory for judging the quantitative presence of unsound chert.

"The bulk specific gravity appears to be closely related to the absorptive capacity of chert which appears to be the principal index of chert durability."

The unsound type of chert which may occur in limestone, as well as in gravel, undoubtedly leads to lack of durability in concrete in general and, in pavements, it may definitely limit their life because of excessive cracking and disintegration. The light porous forms of chert should be avoided in excessive amounts. Cantrill and Campbell[4] do not attempt to state any particular percentage of undesirable chert, but rather, they set up requirements for the coarse aggregate based on tests of concrete. They would specify that:

(a) Coarse aggregate shall not show an absorption greater than 3 per cent when subjected to ASTM Standard Test C95-36. (This is a test requiring boiling for 24 hours.)

(b) Concrete in which any aggregate is incorporated shall not show a reduction in flexural strength greater than 30 per cent when subjected to 40 cycles of freezing and thawing in the presence of water.

Surface Texture

The effect of surface texture of aggregates on the life of a concrete pavement probably cannot be evaluated with any great accuracy. It seems to be a fact, however, that surface texture does influence the bond with the matrix; the smoother the surface, the weaker is the bond. Surface texture seems to influence modulus of rupture, probably because of its effect on the bond between the coarse aggregate and the matrix. The effect of glassy particles in slag has been investigated by the National Slag Association and by the Ohio State Highway Department. The Association found no falling off in beam strength for slag containing up to 30 per cent of glassy pieces; the Ohio laboratory found a reduction in modulus of rupture from 753 for zero per cent glassy pieces to 672 for 100 per cent glassy pieces. Evidently more work is needed to permit of definite conclusions.

3 R. B. Sosman—"The Properties of Silica," *Monograph Series No. 37*, Chemical Catalogue Co., Inc., New York, N. Y., 1927, p. 716

4 Curtis Cantrill and Louis Campbell—"Selection of Aggregates for Concrete Pavement Based on Service Records," *Proceedings*, American Society for Testing Materials, Vol. 39, p. 937

5 William Y. Holland—"Petrography of Aggregates from the TVA," U. S. Dept. of the Interior, Bureau of Reclamation, Denver, Colo.

6 Charles E. Wuerpel & E. P. Rexford—"The Soundness of Chert as Measured by Bulk Specific Gravity and Absorption"; ASTM *Proceedings*, Vol. 40, p. 1021

Flat and Elongated Pieces

There seems to be no well-confirmed evidence that flat and elongated pieces affect the life of a concrete pavement. Theoretically, however, flat and elongated coarse or fine aggregate necessarily leads to a higher water content for a given slump, and a large amount of flat and elongated pieces would so increase the water-cement ratio as to materially affect the durability of a pavement concrete. It is best for producers to be on the safe side and avoid flat and elongated pieces as much as possible. So far as I have been able to ascertain, as applied to crushed stone, shape of fragment produced is largely a matter of reduction ratio when other than impact type crushers are used. A small reduction ratio is favorable for the production of cubical stone. Type of crusher influences the shape of product also, but this is a subject not included in our present discussion.

Unsoundness of Aggregate

Perhaps unsoundness of aggregate may be roughly classified into two general types; first, the type which results in a general breaking down or disintegration of the aggregate without any deleterious swelling, and hence without the exertion of internal pressure in concrete. We have all seen the holes in concrete pavements resulting from the action of freezing on unsound shale. But there is another type of unsoundness which is much more serious; this is the type which results in expansion of the aggregates due to freezing. This type of unsoundness leads to blow-ups and to serious cracking and even disintegation, which definitely limits the pavement life. All three of the principal types of coarse aggregates, gravel, stone, and slag, can show this type of unsoundness, though from different basic causes. Excessive chert in gravel, the presence of hard burned lime in slag, and the inclusion of clay seams in limestone may have detrimental swelling action on concrete under the action of the weather. Some clays are notorious in their volume change due to wetting and drying alone. Blanks[7] states that "clay minerals of the montmorillonite type (bentonite) expand and contract significantly with wetting and drying. The expansion is accompanied by potential pressures which occasionally are several thousand pounds per square inch." He likewise states that "some limestones, although sound according to standard tests, contribute to the deterioration of concrete when their interstitial clay swells as it absorbs water from the concrete." Definitely this action would greatly affect pavement life.

Effect of Pores

Apparently, also, investigations made largely at Purdue as a part of the work of the Joint Research Project, point to other characteristics of aggregates which make for a large amount of expansion under the action of freezing and thawing. This expansion of the aggregate becomes apparent first in the production of excessive blow-ups of the pavement, generally in the spring months, when high moisture content and high temperature have a combined expanding effect on the concrete, which is already in an expanded condition due to the coarse aggregate. It is said that pavements showing excessive blow-ups will shortly develop "D-cracking"—the typical cracks filled with a deposit, probably of calcium carbonate, and these cracks are the forerunners of ultimate disintegration. The excellent work reported by Woods and some of his co-workers, Sweet, Lewis, and no doubt others, seems to tie in these cases of excessive cracking with particular aggregates, and work done elsewhere, notably in Kansas, Missouri, Kentucky, and Iowa, tends to associate particular coarse aggregates with non-durable concrete.

Dr. Sweet,[8] formerly with the Purdue-Indiana Project, concludes that the volume of pores smaller in diameter than 0.005 mm. (about 0.0002 in.) is very critical in controlling the durability of Indiana aggregates. He states, "Materials having a volume of voids smaller than 0.005 mm. of less than 0.06 (per unit of solid volume) had good service records in concrete pavements, while those having a value for this criterion of 0.10 or greater had demonstrated unsatisfactory performance in pavements." I interpret this to mean that when an aggregate has less than 6 per cent by volume of pores or voids less than 0.005 mm. in diameter, the aggregate is safe to use, but when there is more than 10 per cent by volume of this range of pore size, the aggregate is definitely unsafe to use. There seems to be a twilight zone of from 6 to 10 per cent voids which is still somewhat in doubt.

Dr. Sweet came to other important conclusions, which for lack of time cannot be repeated, but

[7] Robert F. Blanks—"Modern Concepts Applied to Concrete Aggregate," *Proceedings*, American Society of Civil Engineers, April 1949

[8] Harold S. Sweet—"Research on Concrete Durability as Affected by Coarse Aggregate," *Reprint* 47, Engineering Experiment Station, Purdue University

his conclusion "5" seems particularly significant. " . . . the limestone aggregates with greater than 3.9 per cent absorption and greater than 0.86 degree saturation when incorporated in concrete in laboratory mixes cause rapid deterioration of the concrete in freezing and thawing. Concrete containing aggregates with an absorption between 2 and 3 per cent and greater than 0.82 degree of saturation was intermediate in resistance to freezing and thawing. Concrete containing aggregate with a degree of saturation less than 0.8 or an absorption less than 2 per cent was highly resistant to freezing and thawing."

By "degree of saturation" is meant the extent to which the voids are filled with water. For illustration, a degree of saturation of 0.8 means that 0.8 of the volume of the voids is filled with water and 0.2 remains unfilled. This "degree of saturation" becomes highly significant when it is remembered that water expands when ice is formed and if insufficient volume is left for that expansion because the pores are too full of water, high internal pressure—either direct ice pressure or high hydrostatic pressure—is created as the ice tends to force the water through the pores.

Blanks[9] points out that the "formation of ice within solid materials results in breakdown through the operation of one or more of three separate processes:

"(a) The development of excessive hydrostatic pressures within materials of low permeability during progressive freezing

"(b) Formation of ice lenses

"(c) The excessive thermal expansion of ice filling voids when temperatures are rising, in the range below the freezing point."

Process "a" has already been referred to, "b", the formation of ice lenses, means the building up of solid ice, perhaps by freezing from the top as capillary water is fed up from the bottom of the slab.

Under "c" it is to be remembered that ice, as a solid material, expands and contracts in its frozen state like other solids and that its thermal coefficient of expansion is about 0.000028 as against about 0.000004 for limestone, and 0.000009 for cement paste. Thus the ice expands roughly from 3 to 7 times as much as the other solids in the concrete, and if the voids are filled with ice, great harm can be done as the ice expands due to rising temperatures. This is an interesting thought.

[9] Robert F. Blanks—"Modern Concepts Applied to Concrete Aggregate," *Proceedings*, American Society of Civil Engineers, April 1949

Effect of Subgrade

Woods, Sweet, and Shelburne[10] have concluded (Conclusion 11) that "deterioration of those pavements susceptible to blow-ups was more rapid on plastic soils than on the more granular soils." They likewise suggest "the possible use of granular base courses to improve concrete durability." The speaker has seen indications that a granular base course prevented map cracking which occurred universally where such a granular base was not used.

It may be of interest to note that the National Crushed Stone Association laboratory is studying this problem of the effect of aggregates on concrete disintegration, making use of expansion measurements on cores subjected to freezing to be followed later by concrete tests. However, we are not ready to report our findings at this time, and I would prefer to come to some definite conclusions before discussing any of our results. There can be no question, however, that some aggregates do expand excessively under certain circumstances due to freezing and thawing, and such aggregates when used in concrete pavements can have a serious effect on the pavement life. However, there may be ways of overcoming these bad effects, most promising of which are (a) allowing surplus water to dry from the aggregate, (b) use of a granular base, and (c) use of air-entrainment. All three tend to decrease the "degree" to which the voids are filled with water.

Chemical Reactivity

You all are familiar with the excessive expansion which takes place due to chemical activity in the hardened concrete. The alkalis, sodium and potassium, in the cement, when present in sufficiently large amounts, generally supposed to be over 0.6 per cent of sodium and potassium oxides, combine with the available silica, to form sodium silicate or potassium silicate. As these silicates are generated, internal pressures are set up in the concrete and cracking and disintegration result.

The minerals which, according to Blanks, are chemically reactive are opal, an amorphous form of silica, chalcedony, and tridymite. The reactive rocks, provided they contain reactive minerals, are opaline cherts, chalcedonic cherts, silicious limestones, several volcanic rocks, such as rhyolite, dacite andesite,

(*Continued on Page 16*)

[10] K. B. Woods, H. S. Sweet & T. E. Shelburne—"Pavement Blow-ups Correlated with Source of Coarse Aggregates"; *Reprint* 22, Engineering Experiment Station, Purdue University

Crushed Stone Output in 1949[1]

By D. G. RUNNER

NAN C. JENSEN

Under the Supervision of G. W. Josephson
Chief, Construction and Chemical
Materials Branch, Minerals Division
U. S. Bureau of Mines
Washington, D. C.

THE output of crushed and broken stone in the United States in 1949, as reported by producers to the Bureau of Mines, United States Department of the Interior, amounted to 222,408,140 short tons valued at $289,695,520—a decrease of 1 per cent in tonnage but an increase of 3 per cent in value. Included in this total are stone sold or used for concrete aggregates, railroad ballast, metallurgical use (flux), agricultural limestone, refractory stone, riprap, in alkali, calcium carbide, sugar and glass factories, in paper mills, and in various other chemical and manufacturing processes. Stone used in the manufacture of open-market lime and cement, asphaltic stone, and slate used for granules and flour are not included in this total.

Crushed and broken stone used for concrete aggregates and railroad ballast (63 per cent of the total output in 1949) increased 1 per cent in quantity and 5 per cent in value over 1948 totals. Eighty-nine per cent of the 124,367,210 short tons used for concrete aggregate was produced by commercial operators and 11 per cent by government agencies.

Metallurgical uses, which took 14 per cent of the total crushed and broken stone in 1949, showed a decrease of 13 per cent quantitywise and a decrease of 7 per cent in value compared with 1948. Limestone for agricultural purposes (10 per cent of total tonnage of crushed stone in 1949) increased 3 and 4 per cent, respectively, in quantity and value over the previous year's figures. Other uses consumed 29,165,540 tons (13 per cent of total) valued at $50,835,269.

In 1949, limestone, including dolomite, constituted 73 per cent of all crushed and broken stone sold (excluding that used for making cement and lime) and was quarried in all but four states.

The following tables present the salient statistics of the crushed and broken stone industries in 1949.

[1] Mineral Market Report MMS No. 1920

CRUSHED AND BROKEN STONE SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1948-49, BY PRINCIPAL USES

Use	1948			1949		
	Short Tons	Value		Short Tons	Value	
		Total	Average		Total	Average
Concrete and road metal	121,542,170	$149,879,694	$1.23	124,367,210	$158,357,911	$1.27
Railroad ballast	18,180,990	16,315,834	.90	17,054,180	15,376,880	.90
Furnace flux [1]	34,901,940	34,250,008	.98	30,338,300	31,874,319	1.05
Alkali works	7,349,540	5,942,572	.81	6,022,240	5,641,705	.94
Riprap	5,707,410	7,553,156	1.32	7,568,390	9,829,626	1.30
Agriculture [1]	20,941,530	32,034,698	1.53	21,482,910	33,251,141	1.55
Refractory stone [2]	2,557,050	6,531,084	2.55	2,386,350	6,327,048	2.65
Asphalt filler	553,360	1,593,820	2.88	671,560	1,893,964	2.82
Calcium carbide works	1,052,080	1,027,952	.98	652,950	654,470	1.00
Sugar factories	471,030	1,098,933	2.33	555,030	1,361,169	2.45
Glass factories	666,360	1,410,120	2.12	621,840	1,373,314	2.21
Paper mills	475,880	908,098	1.91	417,850	766,856	1.84
Other uses	9,464,440	22,414,483	2.37	10,269,330	22,987,117	2.24
Total	223,863,780	$280,960,452	$1.26	222,408,140	$289,695,520	$1.30
Portland and natural cement and cement rock [3]	54,513,000	(4)	.....	55,219,000	(4)	.....
Lime [5]	14,528,000	(4)	.....	12,637,000	(4)	.....
Grand total	292,905,000	(4)	.....	290,264,000	(4)	.....

[1] Limestone
[2] Ganister (sandstone), mica schist, dolomite, and soapstone
[3] Value reported as cement in chapter on "Cement"
[4] No value available for stone used in manufacture of cement and lime
[5] Value reported as lime in chapter on "Lime"

STONE [1] SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1948–49, BY STATES

State	1948		1949	
	Short Tons	Value	Short Tons	Value
Alabama	2,475,530	$4,482,133	2,636,930	$6,039,867
Arizona	307,570	263,157	356,050	203,295
Arkansas	1,379,410	1,883,500	[2] 1,279,250	[2] 2,247,236
California	[2] 11,936,240	[2] 13,155,454	11,373,700	12,594,048
Colorado	2,195,250	2,490,449	[2] 1,816,790	[2] 2,803,538
Connecticut	1,525,490	2,283,298	1,695,650	2,460,547
Delaware	36,390	89,970	37,240	92,100
Florida	[2] 4,154,920	[2] 5,115,974	4,215,090	4,748,253
Georgia	3,631,430	10,801,355	[2] 4,156,220	[2] 8,427,627
Idaho	1,081,060	1,003,858	1,440,680	1,878,801
Illinois	[2] 18,533,290	[2] 22,823,138	17,054,110	20,682,162
Indiana	[2] 6,574,390	[2] 14,989,239	[2] 6,332,360	[2] 15,227,818
Iowa	6,387,620	8,332,682	6,831,190	8,663,201
Kansas	5,315,680	5,481,190	[2] 5,978,420	[2] 7,951,490
Kentucky	6,154,950	7,598,309	7,100,160	8,586,402
Louisiana	[3]	[3]	[3]	[3]
Maine	288,760	2,021,035	258,810	2,025,870
Maryland	1,874,270	3,115,196	[2] 1,789,830	[2] 3,036,410
Massachusetts	[2] 2,367,140	[2] 6,592,952	2,290,940	6,552,935
Michigan	[2] 19,704,150	[2] 14,620,527	16,546,670	13,387,334
Minnesota	1,804,960	5,090,652	1,878,910	5,278,716
Mississippi	24,330	27,980	[3]	[3]
Missouri	[2] 9,020,580	[2] 12,320,220	9,562,720	13,969,008
Montana	614,950	613,024	[2] 602,890	[2] 563,465
Nebraska	366,110	707,327	[2] 504,870	[2] 840,758
Nevada	554,880	680,957	518,510	668,960
New Hampshire	88,430	314,353	6,910	381,141
New Jersey	3,591,440	6,375,877	4,070,790	7,896,619
New Mexico	531,300	293,858	138,290	106,135
New York	12,687,970	17,261,486	13,022,070	18,160,387
North Carolina	5,237,050	7,713,859	6,225,290	10,077,976
North Dakota	[3]	[3]	[3]	[3]
Ohio	20,274,570	27,552,017	[2] 19,364,230	[2] 27,419,158
Oklahoma	4,027,630	4,141,379	4,341,930	4,027,409
Oregon	3,682,420	5,733,658	[2] 4,397,390	[2] 6,479,164
Pennsylvania	23,172,190	35,189,148	21,226,480	34,855,664
Rhode Island	107,080	536,651	[2] 74,670	[2] 451,029
South Carolina	2,443,750	4,543,436	[2] 2,440,540	[2] 3,628,596
South Dakota	763,080	3,911,236	[2] 1,023,710	[2] 4,473,432
Tennessee	8,011,360	12,932,537	[2] 7,613,530	[2] 13,026,948
Texas	[2] 3,844,350	[2] 4,658,720	4,158,430	5,289,647
Utah	279,660	477,654	283,020	427,418
Vermont	395,380	7,992,144	441,770	8,276,287
Virginia	7,366,520	12,157,241	7,509,740	12,442,765
Washington	5,229,500	6,382,462	[2] 3,688,890	[2] 4,105,516
West Virginia	4,929,910	5,802,683	4,854,590	6,960,191
Wisconsin	[2] 7,224,330	[2] 12,581,046	7,326,710	13,636,020
Wyoming	964,460	1,265,694	1,802,580	2,227,096
Alaska, Hawaii, and Puerto Rico	1,060,490	2,324,349	1,477,820	1,999,329
Undistributed	1,313,170	2,259,507	2,279,200	6,163,877
Total	225,535,390	$328,984,571	224,026,570	$341,441,645

[1] Includes—1948: 1,671,610 short tons of dimension stone valued at $48,024,119; 1949: 1,618,430 tons, $51,746,125
[2] To avoid disclosing confidential information, certain state totals are incomplete, the figures not included being combined with "Undistributed"
[3] Included with "Undistributed"

CRUSHED STONE SOLD OR USED IN THE UNITED STATES IN 1949, BY METHODS OF TRANSPORTATION

Method of Transportation	Commercial Operations		Commercial and Non-Commercial [1] Operations	
	Short Tons	Per cent of Total	Short Tons	Per Cent of Total
Truck	101,656,200	50	120,453,760	54
Rail	71,640,310	35	71,640,310	32
Waterway	21,419,240	11	21,419,240	10
Unspecified	8,894,830	4	8,894,830	4
	203,610,580	100	222,408,140	100

[1] Entire output of non-commercial operations assumed to be moved by truck

LIMESTONE (CRUSHED AND BROKEN STONE) SOLD OR USED BY PRODUCERS IN THE UNITED STATES, 1948–49 BY USES

Use	1948		1949	
	Short Tons	Value	Short Tons	Value
Riprap	2,582,300	$3,317,663	2,806,230	$3,503,812
Fluxing stone	34,901,940	34,250,008	30,338,300	31,874,319
Concrete and road metal	82,414,650	99,956,803	85,154,830	106,541,810
Railroad ballast	7,767,130	7,832,978	7,023,280	7,043,095
Agriculture	20,941,530	32,034,698	21,482,910	33,251,141
Alkali works	7,349,540	5,942,572	6,022,240	5,641,705
Calcium carbide works	1,052,080	1,027,952	652,950	654,470
Coal-mine dusting	414,910	1,640,476	284,840	1,130,061
Filler (not whiting substitute)				
Asphalt	553,360	1,593,820	671,560	1,893,964
Fertilizer	612,040	1,155,690	666,260	1,361,999
Other	262,680	841,406	257,540	974,509
Filter beds	19,940	38,985	56,020	100,741
Glass factories	666,360	1,410,120	621,840	1,373,314
Limestone sand	1,033,820	954,544	1,241,340	1,196,921
Limestone whiting [1]	537,230	3,590,757	501,400	3,511,159
Magnesia works (dolomite) [2]	229,200	315,680	241,070	428,723
Mineral food	422,850	1,843,910	413,850	1,837,105
Mineral (rock) wool	40,540	47,053	42,600	50,737
Paper mills	475,880	908,098	417,850	766,856
Poultry grit	72,040	653,087	101,980	904,053
Refractory (dolomite)	1,323,090	1,497,285	1,365,700	1,485,004
Road base	272,640	229,054	934,720	710,369
Stucco, terrazzo, and artificial stone	36,520	381,282	47,670	505,268
Sugar factories	471,030	1,098,933	555,030	1,361,169
Other uses [3]	1,164,220	1,642,181	589,290	926,608
Use unspecified	517,740	663,115	575,160	813,559
Total	166,135,260	$204,868,150	163,066,460	$209,842,471

[1] Includes stone for filler for calcimine, caulking compounds, ceramics, chewing gum, explosives, floor coverings, foundry compounds, glue, grease, insecticides, leather goods, paint, paper, phonograph records, picture-frame moldings, plastics, pottery, putty, roofing, rubber, tooth paste, wire coating, and unspecified uses. Excludes limestone whiting made by companies from purchased stone

[2] Includes stone for refractory magnesia

[3] Includes stone for acid neutralization, athletic-field marking, carbon dioxide, chemicals (unspecified), concrete blocks and pipes, dyes, fill material, light bulbs, motion-picture snow, oil-well drilling, patching plaster, rayons, roofing granules, spalls, and water treatment

Newly Authorized Federal-Aid Funds Apportioned

APPORTIONMENT of $400 million of the $500 million authorized as federal aid to the states for highways in the fiscal year beginning July 1, 1951, was announced recently by the Department of Commerce. The funds were authorized by the Federal-Aid Highway Act approved September 7, 1950.

The apportionment was made using tentative figures for rural and urban population for each of the states. The remaining amount will be apportioned and proper adjustment made when final urban and rural population figures are reported by the Bureau of the Census.

The Act provides $225 million for projects on the federal-aid highway system, $150 million for projects on the federal-aid secondary system, and $125 million for projects on the federal-aid highway system in urban areas.

Funds will be expended under the general procedure in use for many years in which state highway departments propose projects, prepare plans, award contracts, and supervise construction, all subject to federal approval. Federal participation is limited to half the cost except in the public-lands states where participation may be increased above 50 per cent by one-half of the percentage of the area of the state that is public land.

Funds for the federal-aid highway system are apportioned in proportion to area, population and mileage of post roads, each being given equal weight. Funds for federal-aid secondary roads are apportioned in the same manner except that rural population is used rather than total population. Funds for urban projects are apportioned in proportion to population in municipalities and other urban places of 5,000 or more.

In the apportionment made, final figures for 1950 total population of each state were used but the division between urban population and rural population was based on preliminary figures.

The funds apportioned will be available for expenditure until June 30, 1954.

The apportionment of $400 million made after setting aside an amount for administration and research as authorized by law, is given below. The amount yet to be apportioned will increase amounts shown by approximately one-fourth.

State	Sums Apportioned For			
	Federal-Aid Highway System	Secondary or Feeder Roads	Urban Highways	Total
Alabama	$3,738,880	$2,903,455	$1,286,166	$7,928,501
Arizona	2,626,168	1,786,614	320,211	4,732,993
Arkansas	2,940,110	2,350,527	595,361	5,885,998
California	8,131,849	4,187,880	8,097,502	20,417,231
Colorado	3,184,555	2,124,821	824,650	6,134,026
Connecticut	1,124,250	577,500	2,230,536	3,932,286
Delaware	866,250	577,500	162,586	1,606,336
Florida	2,815,821	1,833,933	1,660,893	6,310,647
Georgia	4,394,406	3,353,532	1,374,695	9,122,633

State	Sums Apportioned For: Federal-Aid Highway System	Secondary or Feeder Roads	Urban Highways	Total
Idaho	$2,189,752	$1,549,929	$ 198,742	$3,938,423
Illinois	6,805,765	3,695,957	7,210,879	17,712,601
Indiana	4,202,898	2,893,456	2,404,427	9,500,781
Iowa	4,284,794	3,129,153	1,256,035	8,669,982
Kansas	4,320,317	3,017,426	908,507	8,246,250
Kentucky	3,245,485	2,686,021	1,023,047	6,954,553
Louisiana	2,724,150	1,997,042	817,195	5,538,387
Maine	1,498,567	1,069,838	450,163	3,018,568
Maryland	1,554,030	1,062,979	1,365,176	3,982,185
Massachusetts	2,233,811	820,396	3,743,804	6,798,011
Michigan	5,500,792	3,330,906	4,610,147	13,441,845
Minnesota	4,661,082	3,282,557	1,716,544	9,660,183
Mississippi	3,158,557	2,628,697	596,601	6,383,855
Missouri	5,114,679	3,452,520	2,449,746	11,016,945
Montana	3,582,514	2,462,611	248,626	6,293,751
Nebraska	3,434,968	2,435,185	616,270	6,486,423
Nevada	2,290,666	1,528,458	88,485	3,907,609
New Hampshire	866,250	577,500	311,591	1,755,341
New Jersey	2,288,496	768,588	3,925,036	6,982,120
New Mexico	2,894,910	1,992,184	343,666	5,230,760
New York	8,330,683	3,328,599	13,481,757	25,141,039
North Carolina	4,345,090	3,708,107	1,347,512	9,400,709
North Dakota	2,580,306	1,869,724	190,567	4,640,597
Ohio	6,166,871	3,741,632	5,808,155	15,716,658
Oklahoma	3,800,555	2,716,615	1,144,395	7,661,565
Oregon	3,046,789	2,124,458	768,408	5,939,655
Pennsylvania	6,934,758	4,120,136	7,141,748	18,196,642
Rhode Island	866,250	577,500	652,029	2,095,779
South Carolina	2,393,911	1,977,140	651,251	5,022,302
South Dakota	2,737,783	1,954,194	203,457	4,895,434
Tennessee	3,782,775	2,949,921	1,408,270	8,140,966
Texas	11,425,744	7,638,141	4,269,828	23,333,713
Utah	2,038,560	1,346,199	426,384	3,811,143
Vermont	866,250	577,500	197,827	1,641,577
Virginia	3,357,702	2,644,389	1,269,583	7,271,674
Washington	2,938,454	1,960,987	1,415,700	6,315,141
West Virginia	1,924,872	1,672,009	657,542	4,254,423
Wisconsin	4,193,845	2,918,688	2,032,084	9,144,617
Wyoming	2,202,367	1,493,000	117,594	3,812,961
Hawaii	866,250	577,500	362,448	1,806,198
District of Columbia	866,250	577,500	933,968	2,377,718
Puerto Rico	909,163	948,896	932,206	2,790,265

Highway Research Board Report of Progress, Road Test One-Md[1]

THIS research project which is identified as Road Test One-Md was proposed by the Interregional Council on Highway Transportation which was organized at Columbus, Ohio on December 6, 1949.

The Project is being conducted by the Highway Research Board on behalf of highway departments of Connecticut, Delaware, Illinois, Kentucky, Maryland, Michigan, New Jersey, Ohio, Pennsylvania, Virginia, Wisconsin, and the District of Columbia, with cooperation of the Bureau of Public Roads.

The principal object of the test is to determine the relative effects, on a particular concrete pavement, of the four different axle loadings on two vehicle types. Information, such as will be secured from this experiment is greatly needed for use in appraising the load carrying capacities of existing concrete pavements, for use in designing new pavements and to provide fundamental data that may be useful in framing equitable legislation to govern highway transportation operation.

In its operation the test consists primarily in comparing the relative effects on parallel adjoining lanes of the reinforced concrete pavement under test of two types of trucks, one type loaded to 18,000 and 22,400 lb. on single axles and the other type loaded to 32,000 and 44,800 lb. on tandem axles.

Additional information, which will be of great value to designers of future pavements and to those charged with evaluating the load carrying ability of existing pavements, is being obtained by means of strain measurements of the pavements under various loads and by measurements of strains induced by warping of the slabs due to temperature differentials between the top and bottom of the concrete.

All pertinent data must be carefully analyzed and considered before final conclusions are drawn, however, certain facts relative to the behavior of the test have already been established.

The more significant observations which may be made from the test results to November 1 (after four months of continuous operation) are as follows:

1. Soil tests made on samples obtained throughout the length of the pavement adjacent to the pavement edges and under certain sections of the pavement indicate that there is reasonable uniformity in the soils on the two sides of the pavement.

2. Based on these same soil tests, there is found to be a definite correlation between soil type and pavement behavior. The higher the granular content and the lower the plasticity of the soil, the better the performance. The subgrade soils on this project are typical of the soils underlying a very extensive mileage of concrete pavement throughout the country.

3. The progress of cracking and depression of joints in the test sections has a definite relationship to the occurrence of pumping. Previous research and observation have shown that four basic conditions must be present simultaneously to create a pumping slab. They are: (a) frequent heavy axle loads; (b) subgrade soils of such a nature that they may pump through open joints or cracks or at pavement edges; (c) free water under the pavement; and (d) joints or cracks in the pavement. These conditions were present on this project and pumping resulted.

4. Based on both quality tests and dimension measurements, the concrete in the test sections is of good strength and of the designed thickness.

5. All four sections were damaged as follows by the loads applied:

(a) The 44,800-lb. tandem axle loads caused approximately eleven times as much cracking (lineal feet) as the 32,000-lb. tandem axle loads. This relationship held true over a period of almost four months, that is from 20,000 to 92,000 truck passes in each lane.

(b) The 22,400-lb. single axle loads caused approximately six times as much cracking (lineal feet) as the 18,000-lb. single axle loads. This relationship held true over a period of almost four months, that is from 35,000 to 175,000 truck passes in each lane.

(c) After 84,000 truck passes, 80 per cent of the joints in the section carrying 44,800-lb. tandem axle loads were depressed, whereas, with the same number of truck passes, only 10 per cent of the joints in the section carrying 32,000-lb. tandem axle loads

[1] Condensed

were depressed. (Depressed joints are defined as those joints at which a marked localized settlement of the pavement has occurred accompanied by cracking of the pavement in the vicinity of the joint.)

(d) After 137,000 truck passes, 22 per cent of the joints in the section carrying 22,400-lb. single axle loads were depressed, whereas, with the same number of truck passes, only 2 per cent of the joints in the section carrying 18,000-lb. single axle loads were depressed.

6. (a) After 175,000 truck passes, 8 per cent of the slabs in the section under 18,000-lb. single axle loads and 40 per cent of the slabs under 22,400-lb. axle loads contained cracks which have been analyzed as constituting structural failures due to the application of the test axle loads. Conversely, 92 per cent of the slabs in the 18,000-lb. section and 60 per cent of the slabs in the 22,400-lb. section show no such structural failures.

(b) After 92,000 truck passes, 27 per cent of the slabs in the section under 32,000-lb. tandem axle loads and 96 per cent of the slabs under 44,800-lb. tandem axle loads contained cracks which have been analyzed as constituting structural failures due to the application of the test axle loads. Conversely, 73 per cent of the slabs in the 32,000-lb. section and 4 per cent of the slabs in the 44,800-lb. section show no such structural failures.

To secure complete answers to the many questions involved in the interrelationships between loads, pavements, and subgrades, additional tests under other conditions will be necessary. However, it is apparent that many significant engineering facts are being derived from this test under one typical set of conditions. It is hoped that additional tests can be conducted on both portland cement concrete and bituminous type pavements under other typical conditions.

AGGREGATES AND PAVEMENT LIFE

(*Continued from Page 9*)

and a metamorphic rock, phyllite, in which the active elements are said to be hydro mica or very fine-grained quartz.

Conclusion

In conclusion, aggregates can and do definitely limit the life of concrete pavements. The beam strength and hence frequency of cracking, maintenance expense, and pavement life are influenced by certain inherent characteristics of aggregates—characteristics including that kind of strength measured by the Los Angeles abrasion test, smoothness of surface, and absorption, which affect adhesion, and flat and elongated pieces, which if present in large amounts, will adversely affect the strength of the concrete. Excessive dust or clay coatings also affect concrete strength, and hence resistance to loads.

Unsound aggregates having low weather resistance, such as typified by shale, or shaley limestone, unsound chert of the light porous variety, lime in slag, clay partings in stone or gravel, and the presence of a sufficiently large volume of small diameter pores—all affect concrete durability and hence pavement life.

Aggregates, however, by no means are solely to blame when concrete pavements have a short life. The cement, concrete proportioning, construction practices, a poorly-drained subgrade, the absence of a suitable granular sub-base, wheel loads too heavy for the pavement, ineffective design details—all are culprits in limiting pavement life, and some of them can have a much more rapid effect than any of the influences due to the aggregates.

CINCINNATI CONVENTION

(*Continued from Page 4*)

a Panel Member of the American Arbitration Association, and Chairman of the Negotiating Committee for many companies in the carpet industry. Mr. Hall has negotiated over 250 labor contracts and has mediated and conciliated many labor disputes in the East. He knows his subject from every angle and his discussion should prove of great interest and value.

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Chain Belt Co.
1600 W. Bruce St., Milwaukee 11, Wis.
Rex Conveyors, Elevators, Feeders, Idlers; Drive and Conveyor Chains, Power Transmission Equipment; Concrete Mixers, Pavers, Pumpcrete and Portable Pumps

Continental Gin Co. Industrial Division
4500 Fifth Ave., S., Birmingham 2, Ala.
Conveyors—Belt, Screw, Flight, and Underground Mine; Elevators—Bucket and Screw; Feeders—Apron, Belt, Reciprocating, Table, and Screw; Drives—V-Belts, Chains and Sprockets, Gears and Speed Reducers

Cross Engineering Co.
P. O. Box 16, Carbondale, Pa.
Screen Plates and Sections, Perforated Plate for Vibrating, Rotary and Shaking Screens

Cummins Engine Co., Inc.
Fifth and Union Sts., Columbus, Ind.
Diesel Engines, Fuel Pumps

Deister Machine Co.
1933 East Wayne St., Fort Wayne 4, Ind.
Deister Plat-O Vibrating Screen, Deister Compound Funnel Classifier

Detroit Diesel Engine Division General Motors Corp.
13400 West Outer Drive, Detroit 28, Mich.
Light Weight, Compact 2 Cycle Diesel Engines and "Package Power" Units for All Classes of Service

Manufacturers Division—National Crushed Stone Association
(continued)

Diamond Iron Works, Inc.
1728 N. Second St., Minneapolis 11, Minn.
Jaw and Roll Crushers; Vibrator, Revolving, and Scrubber Screens; Drag Washers; Bucket Elevators; Belt Conveyors; Bins; Apron and Plate Feeders; Portable Gravel and Rock Crushing, Screening, and Washing Plants; Stationary Crushing, Screening, and Washing Plants; Hammermills

Dixie Machinery Mfg. Co.
4200 Goodfellow Blvd., St. Louis 20, Mo.
Dixie Hammermills—Standard and Moving Breaker Plate Non-Clog for Primary and Secondary Crushing

E. I. du Pont de Nemours & Co., Inc.
Wilmington 98, Del.
Explosives and Blasting Accessories

Eagle Iron Works
129 Holcomb Ave., Des Moines, Iowa
Fine Material Screw Washers—Classifiers—Dehydrators; Coarse Material Screw and Log Washers—Dewaterers; Water Scalping and Fine Material Settling Tanks; and "Swintek" Screen Chain Cutter Dredging Ladders

Easton Car and Construction Co.
Easton, Pa.
Heavy-Duty Dump Body Trailers for Rock and Ore, Truck Bodies, and Quarry Cars; Overhead Hoists for Dumping Haulage Units; Electric Heaters for Tar, Asphalt or Bitumen

Ensign-Bickford Co.
Simsbury, Conn.
Primacord-Bickford Detonating Fuse and Safety Fuse

Euclid Road Machinery Co.
1361 Chardon Road, Cleveland 17, Ohio
Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation

Even Spread Co.
P. O. Box 87, Owensville, Ohio
Power Spreaders and Attachments for Agricultural Lime and Fertilizer

Flexible Steel Lacing Co.
4607 Lexington St., Chicago 44, Ill.
Flexco HD Belt Fasteners, Alligator Belt Lacing, Flexco Hinged Belt Fasteners, Alligator Belt Cutters, Alligator Wide Belt Cutters, Alligator V Belt Fasteners, Flex V Belt Fasteners

Frog, Switch & Mfg. Co.
Carlisle, Pa.
Manganese Steel Department—Manufacturers of "Indian Brand" Manganese Steel Castings for Frogs, Switches, and Crossings, Jaw and Gyratory Crushers, Cement Mills, Mining Machinery, Etc., Steam Shovel Parts

General Electric Co.
1 River Road, Schenectady 5, N. Y.
Electric Motors, Controls, Locomotives, Coordinated Electric Drives for: Shovels, Drag Lines, Conveyors, Hoists, Cranes, Crushers, Screens, Etc.; Coordinated Power Generating and Distributing Systems Including Turbine Generators, Switchgear, Transformers, Cable, Cable Skids, Load Center Substations

Gill Rock Drill Co.
Lebanon, Pa.
Well Drill Tools and Supplies

B. F. Goodrich Co.
500 South Main St., Akron, Ohio
Tires, Belting, Other Rubber Products

Goodyear Tire & Rubber Co., Inc.
Akron 16, Ohio
Airfoam; Mechanical Goods—Belting (Conveyor, Elevator, Transmission), Hose (Air Water, Steam, Suction, Miscellaneous), Chute Lining (Rubber); Rims (Truck and Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road, LifeGuard, Safety Tubes, Puncture Seal Tubes

Gruendler Crusher and Pulverizer Co.
2915 N. Market St., St. Louis 6, Mo.
Rock and Gravel Crushing and Screening Plants, Jaw Crushers, Roll Crushers, Hammermills, Lime Pulverizers

George Haiss Mfg. Co., Inc., Division of Pettibone Mulliken Corp.
141st-144th on Park Ave., New York 51, N. Y.
Bucket Loaders, Buckets, Portable and Stationary Conveyors, Car Unloaders

Harnischfeger Corp.
4400 W. National Ave., Milwaukee 14, Wis.
A complete line of Power Excavating Equipment, Overhead Cranes, Hoists, Smootharc Welders, Welding Rod, Motors and Generators, Diesel Engines

HarriSteel Products Co.
420 Lexington Ave., New York 17, N. Y.
Woven Wire Screen Cloth

Manufacturers Division—National Crushed Stone Association
(continued)

Hayward Co.

50 Church Street, New York 7, N. Y.

Orange Peel Buckets, Clam Shell Buckets, Electric Motor Buckets, Automatic Take-up Reels

E. Lee Heidenreich, Jr., Consulting Engineers

67 Second St., Newburgh, N. Y.

Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals—Plant and Property

Hendrick Mfg. Co.

Carbondale, Pa.

Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Open Steel Floor Grating

Hercules Powder Co.

Wilmington 99, Del.

Explosives and Blasting Supplies

Hercules Steel Products Corp.

Sherman St., Galion, Ohio

Ice Control Spinner Type Spreaders, Chain Conveyor Type, Lime and Fertilizer Spreaders, Hydraulic Hoists and Dump Bodies, Split Shaft Power Take-Offs, Hydraulically Operated Lift Gates

Hetherington & Berner Inc.

701-745 Kentucky Ave., Indianapolis 7, Ind.

Asphalt Paving Machinery, Sand and Stone Dryers, Dust Collectors

Hewitt-Robins Incorporated

370 Lexington Ave., New York 17, N. Y.

Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shake-outs; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants

Illinois Powder Mfg. Co.

112 N. Fourth St., St. Louis 2, Mo.

Gold Medal Explosives

Ingersoll-Rand Co.

11 Broadway, New York 4, N. Y.

Rock Drills, Quarrymaster Drills, Jackbits, Bit Reconditioning Equipment, Portable and Stationery Air Compressors, Air Hoists, Slusher Hoists, Air Tools, Diesel Engines, Pumps

Insley Manufacturing Corp.

801 N. Olney St., Indianapolis 6, Ind.

Concrete Carts and Buckets, ½ Yd. Cranes and Shovels

Iowa Manufacturing Co.

916 16th St., N.E., Cedar Rapids, Iowa

Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Hot and Cold Mix Asphalt Plants, Stabilizer Plants, KU-BIT Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills

Jaite Co.

Jaite, Ohio

Multiwall Paper Bags, Sewn and Pasted Style for Packaging Lime, Cement, Plaster, Etc.

Jeffrey Manufacturing Co.

E. First Ave., Columbus 16, Ohio

Material Handling Machinery, Crushers, Pulverizers, Screens, Chains

Joy Manufacturing Co.

333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.

Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists; Multi-Purpose and Portable Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; Drill-Bit Furnaces; "Spaders"; "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core

Kennedy-Van Saun Mfg. and Eng. Corp.

2 Park Ave., New York 16, N. Y.

Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel Co.

505 Kensington Ave., Chicago 28, Ill.

Manganese Steel Castings, Dipper Teeth, Crawler Treads, Jaw Plates, Concaves and Hammers

Keystone Driller Co.

2001-2021 Eighth Ave., Beaver Falls, Pa.

Drills, Power Shovels

King Powder Co., Inc.

Cincinnati, Ohio

Detonite, Dynamites, and Blasting Supplies

Koehring Co.

3026 W. Concordia Ave., Milwaukee 16, Wis.

Excavating, Hauling and Concrete Equipment

Kraft Bag Corp.

630 Fifth Ave., New York 20, N. Y.

Heavy Duty Multiwall Paper Bags

Manufacturers Division—National Crushed Stone Association
(continued)

Lima Shovel and Crane Division
Lima-Hamilton Corp.
South Main St., Lima, Ohio
Power Shovels, Draglines, and Cranes

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, Speed-O-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Ludlow-Saylor Wire Co.
634 S. Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, All Commercial Alloys and Metals

Mack Manufacturing Corp.
350 Fifth Ave., New York 1, N. Y.
On- and Off-Highway Trucks, Tractor Trailers, Six-Wheelers, from 5 to 30 Tons Capacity, both Gasoline- and Diesel-Powered

Marion Power Shovel Co.
617 W. Center St., Marion, Ohio
A Complete Line of Power Shovels, Draglines, and Cranes

McLanahan & Stone Corp.
200 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment —Crushers, Washers, Screens, Feeders, etc.

Murphy Diesel Co.
5317 W. Burnham St., Milwaukee 14, Wis.
Murphy Diesel Engines Ranging from 90 to 190 Continuous Horsepower at 1200 Rpm. and Packaged Type Generator Sets 60 to 133 Kw. for All Classes of Service

N. P. Nelson Iron Works, Inc.
820 Bloomfield Ave., Clifton, N. J.
Nelson Bucket Loaders

Nordberg Mfg. Co.
3073 S. Chase Ave., Milwaukee 7, Wis.
Cone, Gyratory, Jaw and Impact Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens; Grizzlies; Diesel and Steam Engines; Compressors; Mine Hoists; Track Maintenance Tools

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 S. LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels

Osgood Co.
Cheney Ave., Marion, Ohio
Power Shovels, Cranes, Draglines, Hoes, Etc., 3/8 to 2 1/2 Cu. Yd.

Pennsylvania Crusher Co.
Liberty Trust Bldg., Broad and Arch Sts., Philadelphia 7, Pa.
Single Roll Crushers, Impactors, Hammermills, Ring Type Granulators, KUE-KEN Jaw Crushers, KUE-KEN Gyracones

Pettibone Mulliken Corp.
4710 W. Division St., Chicago 51, Ill.
Buckets, Dragline and Parts; Loaders—Car, Bucket; Plants—Asphalt, Portable

Pioneer Engineering Works, Inc.
1515 Central Ave., N. E., Minneapolis 13, Minn.
Jaw Crushers, Roll Crushers (Twin and Triple), Vibrating and Revolving Screens, Feeders (Mechanical, Grizzly, Apron, and Pioneer-Oro), Belt Conveyors, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants

Pit and Quarry Publications
538 South Clark St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Quaker Rubber Corp.
Tacony and Milnor Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Rock Bit Sales and Service Co.
350 Depot St., Asheville, N. C.
Tungsten Carbide Detachable Bits, "Rock Bit" Drill Steel Inlaid with Tungsten Carbide, Carbon Hollow Drill Steel, Alloy Hollow Drill Steel

Rock Products
309 West Jackson Blvd., Chicago 6, Ill.

John A. Roebling's Sons Co.
Woven Wire Fabrics Division
Roebling, N. J.
Aggregate Screen, Hardware and Industrial Wire Cloth, Insect Screening, Wire Rope, Fittings and Strand, Slings, Suspension Bridges and Cables, Aerial Wire Rope Systems, Ski Lifts, Electric Wire and Cable, Magnet Wire

Manufacturers Division—National Crushed Stone Association
(concluded)

St. Regis Sales Corp.
933 Mathieson Bldg., Baltimore 2, Md.
Main Office: 230 Park Ave., New York 17, N. Y.
Automatic Filling and Weighing Machines and Multiwall Paper Shipping Sacks

Sanderson-Cyclone Drill Co.
South Main St., Orrville, Ohio
All Steel Wire Line, Air Speed Spudders, Large Blast Hole Drills, Drilling Tools and Drilling Supplies

Schield Bantam Co.
Waverly, Iowa
Bantam Trench Hoes, Draglines, Clams, Shovels

Screen Equipment Co.
1754 Walden Ave., Buffalo 21, N. Y.
SECO Vibrating Screens

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screen, Simplicity D'centegrator, Simplicity D'watering Wheel

Smith Engineering Works
532 E. Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman's Foundry & Machine Works
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Taggart Corp.
(See St. Regis Sales Corp.)

W. O. & M. W. Talcott, Inc.
91 Sabin St., Providence 1, R. I.
Belt Fasteners, Belt Lacing, Conveyor Belt Fasteners, and Patch Fasteners

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and other Special Alloy Steel Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
Power Shovels, Cranes, Crawler Cranes, Locomotive Cranes, Draglines, Diesel Electric, Gasoline, 3/8 to 2 1/2 Cu. Yd. Capacities

Torrington Co.
Bantam Bearings Division
3702 W. Sample St., South Bend 21, Ind.
Anti-Friction Bearings (All Types and Sizes)

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 N. 7th St., Allentown, Pa.
Explosives and Blasting Supplies

W. S. Tyler Co.
3615 Superior Ave., N. E., Cleveland 14, Ohio
Wire Screens, Screening Machinery, Scrubbers, Testing Sieves and Dryers

Universal Engineering Corp.
625 C Ave., N. W., Cedar Rapids, Iowa.
Jaw Crushers, Roll Crushers, Hammermills, Complete Crushing, Screening, and Loading Plants, Either Stationary or Portable for Stone Aggregates or Aglime

Vibration Measurement Engineers
7705 Sheridan Rd., Chicago 26, Ill.
Specialists in Blasting Complaint Investigations; Seismological Surveying; Expert Testimony in Blasting Litigation

Waukesha Motor Co.
E. St. Paul Ave., Waukesha, Wis.
Engines—Diesel, Gas, and Gasoline, Both Independent and as Complete Power Plants, Portable in Smaller Sizes, and Semi-Portable in Largest Sizes, Horsepower Range from 5/8 to over 500 Hp.

NATIONAL CRUSHED STONE ASSOCIATION
NCSA
1918